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Title: FY18 J23X PSDT Final Report: Shock Initiation of PBX 9502 Lot HOL88H891-008

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FY18 J23X PSDT Final Report: Shock Initiation of PBX 9502 Lot HOL88H891-008

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I. ABSTRACT

This report details a series of plate impact experiments on the insensitive explosive PBX 9502 (95% TATB, 5% Kel-F 800) with lot number HOL88H891-008. This is a 'virgin' lot (no recycled material used), for which many detonation performance measurements are available; the addition of these 1-D shock initiation experiments will aid model calibration efforts for this material. Samples were machined from isostatically-pressed billets with a nominal density of 1.89 g/cc. The evolution of the shock to a detonation was characterized by 9 embedded magnetic particle velocity gauges, and 116 embedded magnetic time of arrival gauges (AKA shock trackers). Photon Doppler velocimetry (PDV) with a LiF window was used at the back surface of the samples to capture the wave profile exiting the sample. Six experiments were performed, covering a pressure range of 10.8–18.6 GPa and run distances to detonation of 2.7–12.2+ mm. The shock initiation of this lot is found to be consistent with Pop plots reported for other lots of PBX 9502. All data have been uploaded to the LANL Small Scale Database for use by the research community.

II. INTRODUCTION

Generation of accurate computational material models for high explosives (HE) require detailed experimental data covering the range of conditions across which the model is expected to be predictive. For maximal accuracy, due to lot-to-lot variability in the manufacture of HE, it is desirable to obtain experimental data for each material lot of interest. This report details a series of plate impact experiments on the insensitive explosive PBX 9502 (95% TATB, 5% Kel-F 800) with lot number HOL88H891-008. An array of detonation experiments are available for this lot, but prior to this work, no 1-D shock initiation data were available. 1-D Shock initiation of this lot was evaluated using impactors accelerated by a two-stage gas gun and an embedded particle velocity gauge technique[1]. These gauges provide a detailed look at the shock to detonation transition (SDT) process by capturing particle velocity histories at multiple locations as chemical reactions develop behind the shock and it ultimately transitions to a detonation.
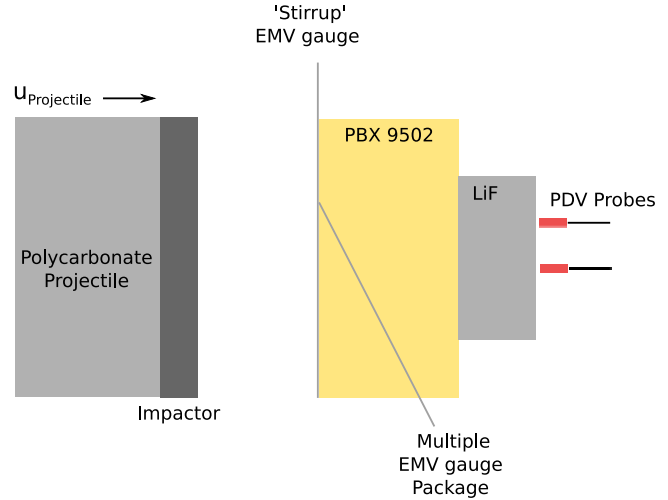

FIG. 1. Schematic of the setup used in these experiments. An embedded gauge is glued between a pair of PBX 9502 wedges and impacted by a Kel-F81 or sapphire impactor.

III. EXPERIMENTAL SETUP

All experiments were conducted on the LANL TA-40 Chamber 9 two-stage gas gun. Billets of PBX 9502 lot HOL88H891-008 were isostatically pressed at 110 degrees C to a nominal density of 1.89 g/cc, and machined into right cylindrical wedges with a 30 degree wedge angle. Pairs of wedges were assembled into right cylinders (nominally 43mm∅ and 23 mm tall) with an embedded electromagnetic velocity (EMV) gauge package glued between them. Each gauge package includes 9 particle velocity gauges beginning at a nominal depth of 1 mm with 0.8 mm spacing between them. In addition, each package includes 'shock tracker' elements, which provide a time of arrival diagnostic at 116 points between 1.2–12.2 mm of depth in the target. A 'stirrup' EMV gauge was also glued to the impact face of the target. The gauges consist of Al conductors sandwiched between FEP Teflon, and produce a voltage proportional to local particle velocity as they move through a static magnetic field[1]. All glue bonds were made with with EPO-TEK 301 epoxy, with typical bond thicknesses of 1–2 microns. The configuration of this experiment is shown in Fig. 1. Two photon Doppler velocimetry (PDV) probes were used to obtain wave profiles on the back surface of the target through an Al coated 25 mm∅ x 12 mm LiF window. A total of 6 single-shock experiments were conducted, 5 of which used Kel-F81 impactors, and the 6th using a sapphire im-

TABLE I. Summary of this series of shock initiation experiments in PBX 9502. P and u_p were calculated based on impedance matching with the Aslam[2] PBX 9502 reactant EOS.

| Shot #	Rho0 g/cc	Impactor	Impactor Velocity km/s	Pressure Gpa	u_p km/s	X_D mm	t_D us
2s-1029	1.893 ±0.001	Kel-F81	2.389 ±0.001	10.83 ±0.3	1.309 ±0.025	>12.2	>2.4
2s-1028	1.892 ±0.001	Kel-F81	2.703 ±0.001	13.01 ±0.3	1.154 ±0.025	7.5 ±0.2	1.3 ±0.05
2s-1035	1.892 ±0.001	Kel-F81	2.788 ±0.001	13.63 ±0.3	1.351 ±0.025	7.0 ±0.2	1.2 ±0.05
2s-1036	1.895 ±0.001	Kel-F81	3.087 ±0.002	15.90 ±0.3	1.501 ±0.025	4.1 ±0.2	0.6 ±0.05
2s-1037	1.893 ±0.002	Kel-F81	3.423 ±0.004	18.62 ±0.3	1.67 ±0.025	2.7 ±0.2	0.4 ±0.05
2s-1038	1.892 ±0.001	Sapphire	1.972 ±0.001	16.3 ±0.3	1.53 ±0.025	3.3 ±0.2	0.56 ±0.05
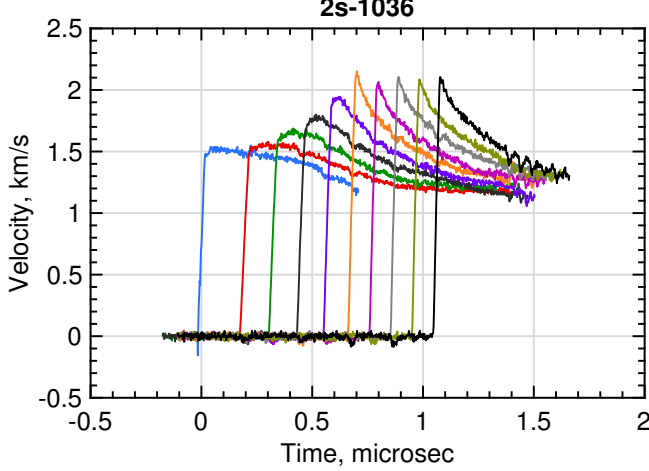
FIG. 2. Wave profiles from embedded particle velocity gauges (15.9 GPa input condition, shot number 2s-1036).

FIG. 3. Window-corrected velocity from PDV on back face of target (15.9 GPa input condition, shot number 2s-1036).

pactor. Full details of each experiment, including geometry and density of the HE samples, impactor and window thicknesses, gauge locations, x-t plots, and tabulated particle velocity data are available for each experiment on the LANL small scale database.

IV. RESULTS

Table I lists summary data for all the PBX 9502 shots in this series. Impact conditions are calculated by impedance matching. The equations of state used for the Kel-F81, Sapphire, and PBX 9502 were obtained from references by Sheffield, Marsh, and Aslam, respectively.[2-4]

A. Wave Profiles

Figure 2 shows wave profiles from the embedded electromagnetic particle velocity gauges at a 15.9 GPa input condition (shot 2s-1036). Wave profiles for all 6 shots of this series are included as an appendix (Figure 5).Transition to detonation is observed in the gauges in all cases except at the 10.8 GPa input condition (shot
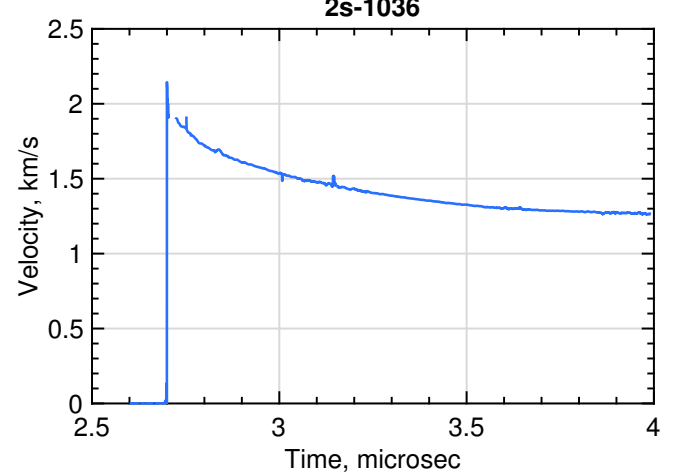
2s-1029). SDT occurs as expected in a heterogeneous explosive[5]; exothermic reactions occur near the shock front that gradually build up the observed particle velocity. Particle velocity histories in this reactive growth phase exhibit a characteristic 'reactive hump' behind the shock front. This continuous reactive growth eventually leads to the formation of a steady detonation with a sharp peak in particle velocity followed by Taylor decay.

B. Photon Doppler Velocimetry

PDV wave profiles were obtained from the output surface of each sample (nominally 23 mm from the impact face) through a LiF window. A window correction was made based on the methods of Rigg.[6] In all cases a similar interface velocity, consistent with a detonation wave, was observed; for brevity only one PDV wave profile is reproduced here (shot 2s-1036).

C. PBX 9502 Pop-plot

Figure 4 shows the published fit to the Pop-plot of PBX 9502 at 296 K (solid line)[7], and single shock experiments
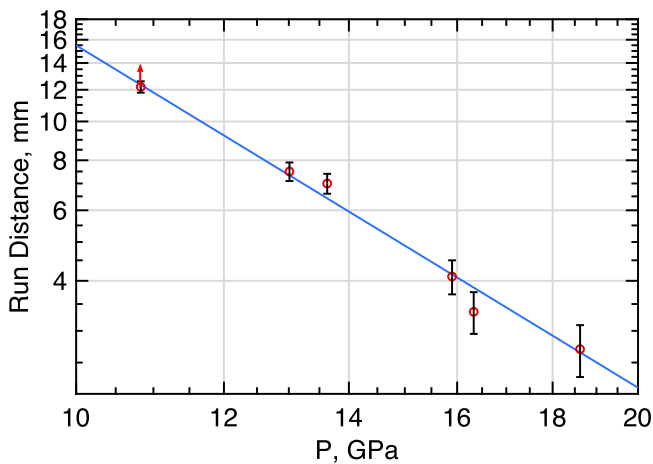
FIG. 4. Pop-plot for PBX 9502 from Gustavesen[7] (line), and single shock experiments on this lot (red circles).

on this lot of PBX 9502 (circles). The single shock data from this series is consistent with the published Pop plot, which was fit using data from 5 other PBX 9502 lots, including both virgin and recycled material.

V. CONCLUSION

A 6-shot series of plate impact SDT experiments were performed on PBX 9502 lot HOL88H891-008 using the two-stage gas gun facility at TA-40 Chamber 9. Lot HOL88H891-008 is a virgin lot containing no recycled material. Shock conditions of 10.8–18.6 GPa were ex-

plored, producing run distances to detonation of 2.7–12.2+ mm. SDT was observed by an embedded magnetic particle velocity and time of arrival gauge, and detonation wave profiles were observed at the back surface of the samples by PDV. Results were consistent with similar experiments on other lots of PBX 9502 (both virgin and recycled). All data have been uploaded to the LANL small scale database for use in calibration and verification & validation of computational models.

VI. REFERENCES

[1]S. Sheffield, G. R.L., and R. Alcon *APS Shock Compression of Condensed Matter - 1999*, p. 1043, 1999.
[2]T. D. Aslam, "The reactants equation of state for the tri-amino-tri-nitro-benzene (tatb) based explosive pbx 9502," *Journal of Applied Physics*, vol. 122, no. 3, p. 035902, 2017.
[3]S. P. Marsh, "Lasl shock hugoniot data," *University of California Press*, 1980.
[4]S. A. Sheffield and R. R. Alcon, "In-situ magnetic gauge measurements in kel-f," *Shock Compression of Condensed Matter - 1991*, 1991.
[5]D. D.M., S. A. Sheffield, S. D.B., D. A.M., T. W., and E. R., "Influence of hot spot features on the initiation characteristics of heterogeneous nitromethane," *14th International Detonation Symposium*, p. 611, 2010.
[6]P. A. Rigg, M. D. Knudson, R. J. Scharff, and R. S. Hixson, "Determining the refractive index of shocked [100] lithium fluoride to the limit of transmissibility," *Journal of Applied Physics*, vol. 116, no. 3, p. 033515, 2014.
[7]R. L. Gustavsen, B. D. Bartram, L. L. Gibson, A. Pacheco, J. D. Jones, and A. B. Goodbody, "Shock initiation of the tatb-based explosive pbx 9502 heated to 130°c," *AIP Conference Proceedings, APS SCCM St. Louis*, 2017.
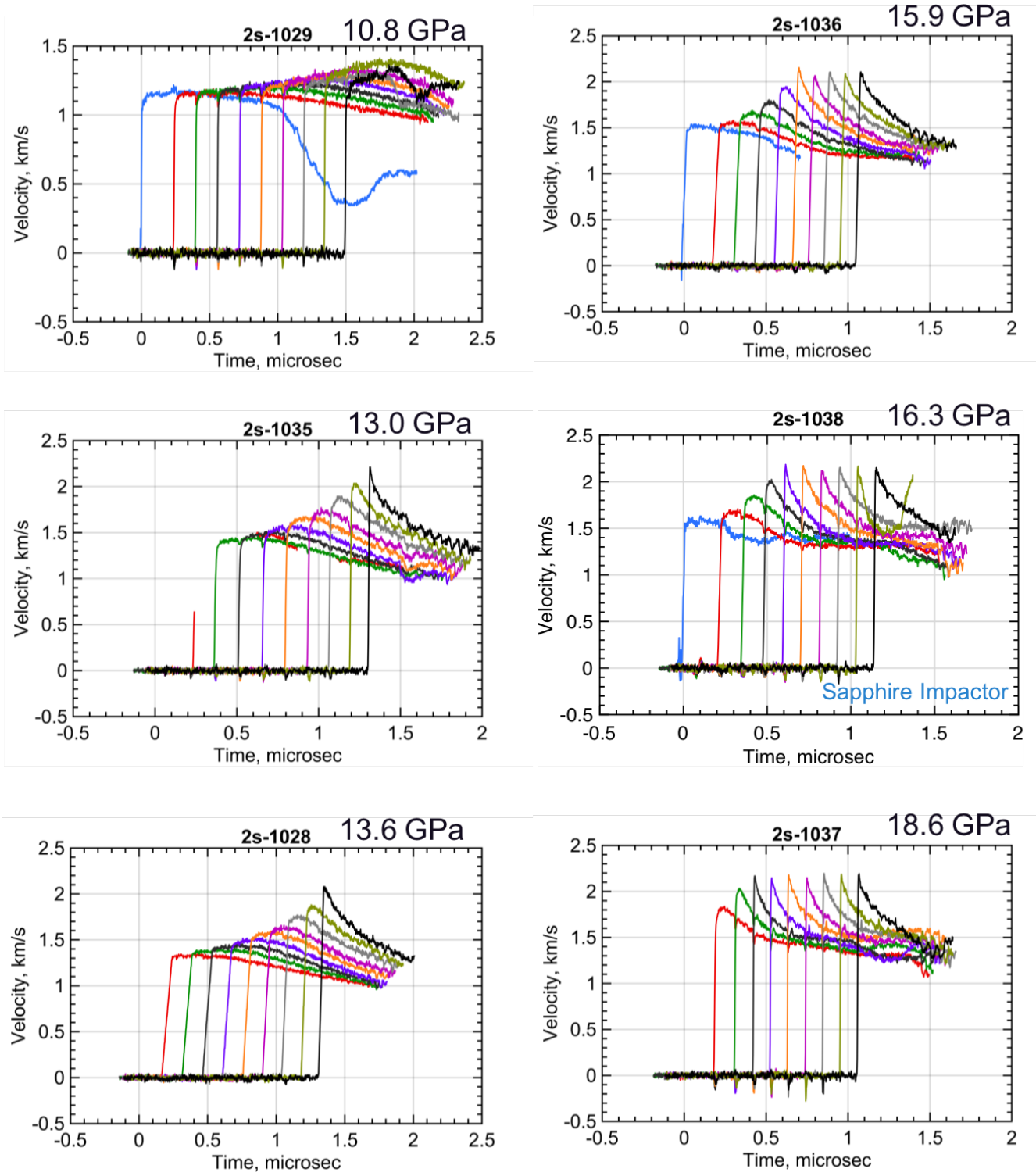
FIG. 5. Wave profiles from embedded particle velocity gauges.